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An investigation of the treatment of a silver ore by lixiviation with sodium and cuprous thiosulphate solutions

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THESIS
FOR THE
Degree of Bachelor of Science
IN
MINE ENGINEERING.

E. E. JONES.

7521

SUBJECT.

**"An Investigation of the Treatment of a Silver Ore by Lixiviation with
Sodium and Cuprous Thiosulphate Solutions."**

JUNE, 1907.

MSM
HISTORICAL
COLLECTION

AN INVESTIGATION OF THE TREATMENT
OF A
SILVER ORE
BY LIXIVIATION WITH SODIUM AND CUPROUS THIOSULPHATE
SOLUTIONS.

The object of this investigation is to find whether the ore can be treated with profit by lixiviation and to find the best conditions for maximum extraction.

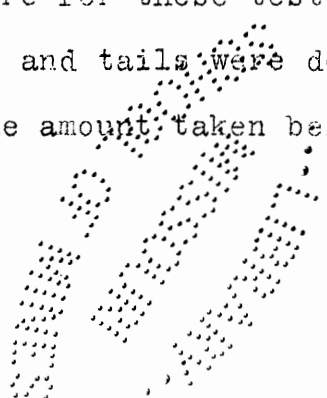
To arrive at any definite conclusion the following points have to be investigated:

- 1 How fine the ore has to be crushed.
- 2 Whether the ore can be lixiviated raw or required roasting.
- 3 The loss of silver in roasting by volatilization.
- 4 the difference between lixiviation with Sodium Thiosulphate and Cuprous Thiosulphate.
- 5 The percentage of NaCl required for the chloridizing roast.
- 6 The minimum strength of $\text{Na}_2\text{S}_2\text{O}_3$ solution.
7. The minimum amount of Cuprous Thiosulphate or Russel Solution needed.

Apparatus.

Beakers of about 750 CC capacity were needed for lixiviation of the ore, funnels about three inches in diameter and filter papers about four inches in diameter for the filtration of the solution.

The balances used for weighing the ore for these tests were Ainsworth balances. The assay of the ore and tails were done in a muffle furnace by the crucible method, the amount taken being too large for scorification.



The charge used for these assays was:

Ore.	.5 A.T.
PbO	20 grams
NaHCO ₃	30 "
Charcoal Dust	3. "
Borax	3 "

Salt Cover.

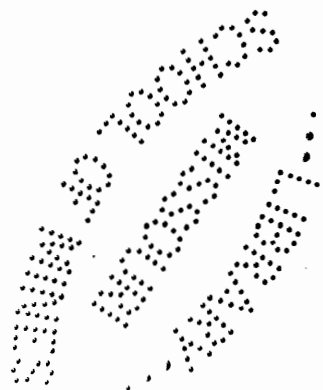
The silver buttons were weighed on Ainsworth Balances and parted for gold.

The balances used in the Quantitative Analysis of the ore were Becker Bros. Analytical Balances. Centigrade Thermometers were used and time recorded by an Elgin watch.

For roasting the apparatus used was clay roasting dishes, six inches in diameter, an assayers muffle furnace and a porcelain tipped stirrer.

The ore on which these experiments were performed showed from analysis the following constituents:

PbCO ₃	4.55%
CaCO ₃	37.79"
MgCO ₃	19.28"
Fe ₂ O ₃	4.37"
Al ₂ O ₃	4.06
SiO ₂	30.40"
Cu	Trace
Ag	27.09 oz
Au	None.



3.

The method of procedure in the analysis was as follows:

Lead

Was determined gravimetrically and weighed as PbSO_4

Amount of ore taken = 2 grams

Weight of PbSO_4 = .1033 "

Percent of Pb in PbSO_4 = 68.318"

Weight of Pb in PbSO_4 is $.1033 \times 68.317 = .7057$

Percentage of Pb in ore is 3.525 To convert into the carbonate. Pb = 207 O = 16, C = 12, $\text{PbCO}_3 = 267$

$$207 : 267 = 3.53 : X$$

$$X = 4.55 = \text{percent of } \text{PbCO}_3$$

Silica

Was determined gravimetrically as SiO_2

Weight of ore = 2 grams

"

" " SiO_2 = .6087 "

percentage of SiO_2 = 30.43 "

Silver and Gold

Were determined by the crucible assay and silver was 27.09 oz. per ton or .09%. No gold.

Copper Only a trace.

Iron and Aluminum

Were determined together gravimetrically as oxides. Then iron determined by KMnO_4 solution.

1 CC KMnO_4 = .0102 grams Fe. Titration used 3 CC of KMnO_4 Solution $3 \times .0102 = 3.06\%$ Fe.

To change this into Fe_2O_3 we have Fe = 53

O = 16 or $\text{Fe}_2\text{O}_3 = 760$

$$112: 160 :: 3.06 : X$$

$$X = 4.37\% \text{ Fe}_2\text{O}_3$$

Weight of $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 = .842$

Percent of Al_2O_3 is $.843 - .437 = 4.06$ taking one gram of the ore.

Calcium.

was determined volumetrically by KMnO_4

Amount of ore used = 1 gram

Number of CC KMnO_4 used = 41.5

Each CC for Iron = .0102

Each CC for CaO = .0057

To find the percentage of CaO in ore;

$$(.0057 \times 41.5) 100 = 21.16$$

To convert CaO into CaCO_3 Ca = 40 C = 12

O = 16 CaO = 56 and $\text{CO}_2 = 44$

$$21.16 : X :: 56 : 44$$

$X = 16.63$ percentage of CO_2 necessary to convert

21.16 percent CaO into CaCO_3 or $\text{CaCO}_3 = 21.16 + 16.63 = 37.79$

Magnesium.

Determined gravimetrically as MgO and = 9.18%. This was converted into carbonate like CaO was converted into CaCO_3

$$\text{MgCO}_3 = 19.28\%$$

The ore was first sampled and assayed, running 27.09 ounces of silver per ton and no gold.

5.

This sample was then crushed and the following sizes obtained:

12,24,40,50,60,80,90, and 100 mesh,all fair samples.

The first experiment was to determine the best size to which the ore should be crushed and the following results were obtained by treating five assay tons of ore with 250 CC of a fine percent solution of $\text{Na}_2\text{S}_2\text{O}_3$ and allowed to stand for seventeen hours.

Table of Results.

No. of mesh	Assay of ore	Time hrs.	Assay Tails.	% Extraction
12	27.09	17	23.82	12.07
24	"	"	23.14	14.21
40	"	"	23.30	13.99
50	"	"	23.36	13.76
60	"	"	24.53	9.45
80	"	"	23.53	13.14
90	"	"	23.12	14.65
100	"	"	23.04	14.90

As seen from the above results this method of treatment is not profitable so another experiment was tried by heating these different sizes with the same amount of solution of the same strength up to 55 C for one hour and allowing them to stand for another hour.

The following results were obtained:

Table of Results.

No of Mesh	Assay of ore	Time hours	Assay Tails	% Extraction.
12	27.09	2 hrs	23.08	24.76
24	"	"	21.72	22.03
40	"	"	20.50	24.30
50	"	"	20.04	26.02
60	"	"	20.35	24.88
80	"	"	20.25	25.36
90	"	"	21.64	23.84
100	"	"	19.80	26.91.

From the two preceding tables the conclusion is reached that the size of the ore is not a matter of particular importance since all the different sizes gave about the same results.

Since the last results show a very poor percentage of extraction, the following tests with Russell's solution were made on the raw ore.

Russell's solution is made by taking 2.25 parts of $\text{Na}_2\text{S}_2\text{O}_3 + 5 \text{H}_2\text{O}$ and one part of $\text{CuSO}_4 + 5 \text{H}_2\text{O}$ by weight. A small amount of free H_2SO_4 is also present

These tests were carried on without any regard to size, the ore used being a mixture of the different meshes.

I The solutions used cold

II The solution heated.

(1) .5 assay tons of ore was treated with 250 CC cold H_2O and 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$, allowed to stand for twelve hours, decanted when 25 CC Russell's solution was added, diluted to 300 CC with

cold H_2O , allowed to stand for twelve hours, 20 grams $Na_2S_2O_3$ and 25 CC of Russell solution added, allowed to stand for twelve hours more, filtered and washed.

Assay of the tails showed 9.52 ounces per ton or 64.85 percent extraction.

(2) .5 assay tons treated with 250 CC cold H_2O and 20 grams $Na_2S_2O_3$, allowed to stand twelve hours, added 20 grams $Na_2S_2O_3$ and 25 CC $CuSO_4$, allowed to stand twelve hours more, filtered and washed.

Assay of the tails showed 7.41 ounces per ton or 72.64 percent extraction.

(3) .5 assay tons ore treated with 100 cc cold H_2O and 25 cc $CuSO_4$, allowed to stand twelve hours, diluted to 300 CC with cold H_2O , added 20 grams $Na_2S_2O_3$, allowed to stand twelve hours, filtered and washed.

Assay of tails showed 4.28 ounces per ton or 84.2 percent extraction.

TESTS ON RAW ORES WITH RUSSELL'S SOLUTION.

(1) To .5 assay tons of ore 100 CC of cold H_2O and 25 CC of $CuSO_4$ were added, allowed to stand for one hour. Then 200 CC of cold H_2O and 20 grams $Na_2S_2O_3$ were added and mixture heated to 55 degrees C. filtered and washed.

Assay of tails showed 11.8 ounces per ton or 56.4 percent extraction.

(2) To .5 assay tons of ore 200 CC of cold H_2O and 25 CC $CuSO_4$ were added, allowed to stand for one hour, 20 grams of $Na_2S_2O_3$ were added and solution heated to 55 degrees C. and then decanted. 100 CC cold H_2O and 25 CC $CuSO_4$ were added, allowed to stand for one

hour when 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$ were added, heated to 55 degrees C for one hour, filtered and washed.

Assay of tails showed 3.92 ounces per ton or 85.5 percent extraction.

(3) To .5 assay tones ore 250 CC of cold H_2O and 25 CC of CuSO_4 were added and heated to 55 degrees C. Allowed to stand one hour, decanted and 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$ and 25 CC of CuSO_4 were added and diluted to 300 CC with cold H_2O . Heated to 55 degrees C, allowed to stand for one hour, filtered and washed.

Assay of tails showed 8.76 ounces per ton or 71.3 percent extraction.

(4) To .5 assay tons, 200 CC of hot H_2O and 90 CC of CuSO_4 were added and allowed to stand for half an hour, 90 grams $\text{Na}_2\text{S}_2\text{O}_3$ added heated to 65 degrees C allowed to stand one hour, filtered and washed.

Assay of tails showed 5.6 ounces per ton or 79.27 percent extraction.

The CuSO_4 solution used in all the tests was made by dissolving 20 grams of ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) in 100 grams of H_2O

The results obtained from all these experiments have so far been satisfactory so the conclusion is reached that this ore can be lixiviated raw.

The ore was given a chloridizing roast to determine the difference in percentage of extraction between the raw and roasted ore and to determine the loss of silver by volatilization during roasting.

For these tests 100 grams of ore were taken and mixed with 10 grams of anhydrous NaCl and roasted for different periods of

time beginning at a low heat.

Table of Results.

Time of Roast	Weight of ore aft. Roasting	Assay of Roasted ore	Amt. of Ag lost by volatilization	Percentage of Extraction
1 hour	78.85	38 oz. per ton	.0128 mg	71.8
.5 "	90.15	29.62 " "	.0016 "	1.7
.75 "	88.82	27.05 " "	.01039 "	11.18

It is not always possible to obtain by muffle roasting on a small scale the same effect that can be obtained by actual mill practice and hence an unfavorable result is not a proof that the ore is unsuitable for lixiviation when necessary to roast it.

To determine whether the $\text{Na}_2\text{S}_2\text{O}_3$ solution could be used with profit for the treatment of the roasted ore, a series of experiments were performed using a five percent solution and allowing them to stand for different periods of time. The amount of ore taken was .5 assay tons in each case.

Results.

Time	Assay of roasted ore	Assay of Tails	Percent of Extraction
8 hrs	27.05 oz to ton	13.16	51.35
12 "	"	12.50	53.78
14 "	"	12.37	54.38
16 "	"	12.15	55.08
18 "	"	12.00	55.45

As this extraction is low it is concluded that this simple solution is not a profitable one to use, so eight determinations on the ore with Russell solution were made to find the percentage of extraction it would give.

Roasted Ores.

One half assay ton of ore leached with hot water. Heads assay 24.86 ounces per ton.

(1) Added 50 CC cold H_2O and 25 CC $CuSO_4$ with cold H_2O , add 20 grams $Na_2S_2O_3$ allowed to stand two hours, filtered and washed.

Assay of tails showed 7.72 ounces per ton or 68.9 percent extraction.

(2) Added 250 CC cold H_2O and 25 CC $CuSO_4$ and allowed to stand twelve hours, added 20 grams $Na_2S_2O_3$ allowed to stand twelve hours filtered and washed.

Assay of tails showed 11.06 ounces per ton or 55.5 percent extraction.

(3) Added 250 CC cold H_2O and 25 CC $CuSO_4$ to .5 assay tons allowed to stand two hours. Added twenty grams $Na_2S_2O_3$ and allowed to stand two hours, filtered and washed.

Assay of tails showed 4.66 ounces per ton or 81.2 percent extraction.

(4) To .5 assay tons add 250 cc cold H_2O and 25 CC $CuSO_4$ and allowed to stand one hour. Added 20 grams $Na_2S_2O_3$ heated to 55 degrees C. and decanted. Added 250 CC cold H_2O and 25 CC $CuSO_4$ and allowed to stand one hour and added 20 grams $Na_2S_2O_3$ heated to 55 degrees C. filtered and washed.

Assay of tails showed 7.64 ounces per ton or 69.2 percent extraction.

First Leach with Water.

(5) Leached .5 assay tons with 300 CC cold H₂O.

Head assay 24.86 ounces.

Added 25 CC CuSO₄ diluted to 300 CC with cold H₂O and allowed to stand twelve hours. Added twenty grams Na₂S₂O₃ and allowed to stand twelve hours, filtered and washed with Na₂S₂O₃ solution.

Assay of tails showed 8.58 ounces per ton or 65.5 percent extraction.

(6) Leached .5 assay tons with 300 CC hot H₂O . Added 200 CC hot H₂O and 90 CC CuSO₄ and allowed to stand half an hour. Added 90 grams Na₂S₂O₃ heated to 65 degrees C. let stand one hour, filtered and washed.

Assay of tails showed 5.76 ounces per ton or 76.8 percent extraction.

(7) Leached .5 assay tons with 300 CC hot H₂O

Added 90 CC CuSO₄ and allowed to stand half an hour, added 20 grams Na₂S₂O₃ diluted to 300 CC. Heated to 65 degrees C. allowed to stand one hour, filtered and washed.

Assay of tails showed 3.56 ounces per ton or 85.7 percent extraction.

(8) Leached .5 assay tons with 300 cc hot H₂O.

Added 20 grams Na₂S₂O₃ and allowed to stand with about 40cc of residue of wash water for one hour. Added 25 cc CuSO₄ diluted to 300 cc with cold H₂O, heated to 55 degrees C, allowed to stand one hour, filter and wash.

Assay of tails showed 3.84 ounces per ton or 84.5 percent extraction.

From all these experiments it was concluded that it was useless to roast the ore but as a matter of investigation, the most economical percentage of NaCl for chloridizing roasting was determined.

This experiment was performed by using the following mixture of anhydrous NaCl and 100 grams of ore:

2,4,6,8,10,12, and 14 percent of NaCl.

These mixtures were roasted for half an hour, assayed and lixiviated with Russells solution in the following manner:

First leach with 300 cc of hot H_2O and decant. Add 20 grams $Na_2S_2O_3$ and allow to stand with about 40 cc of wash water for one hour. Add 25 cc $CuSO_4$, dilute to 300 cc with cold H_2O , heat to 25 degrees C. filter and wash. Assayed residue with the following results:

Results.				
Percentage of NaCl	assay ore	Amt. lost by volatilization	Assay of Residue	Percent of Extraction
2	32.2	.00760 mg	5.86	81.8
4	33.18	.00106 "	5.30	84.42
6	29.82	.00110"	5.42	85.1
8	29.64	.00190 "	4.42	85.2
10	30.66	.01210 "	4.36	86.1
12	28.00	.00410 "	4.24	85.1
14	28.18	.01000"	4.24	85.1

Having found in these various experiments that the raw ore can be treated profitably by lixiviation with Russel Solution the following experiments were performed to determine the minimum amount of $CuSO_4$ and $Na_2S_2O_3$ for maximum extraction.

(1) Treated .5 assay tons of raw ore with 250 cc cold H_2O and added five cc of $CuSO_4$ solution. Let stand for one hour. Added five grams of $Na_2S_2O_3$ heated to 55 degrees C. and decanted. Added 100 cc of cold H_2O , 5 cc $CuSO_4$ /Let stand for one hour and added five grams $Na_2S_2O_3$ heated to 55 degrees C. filtered and washed .

Assay of tails showed 10.85 ounces per ton or 59.94 percent extraction.

(2) Treated .5 assay tons raw ore with 250 cc of cold H_2O . added 10 cc $CuSO_4$.Let stand one hour and added 10 grams $Na_2S_2O_3$, heated to 55 degrees C. and decanted. Added 100 cc cold H_2O and 10 cc $CuSO_4$ allowed to stand one hour. Added 10 grams $Na_2S_2O_3$ heated to 55 degrees C. filtered and washed.

Assay of tails showed 10.24 ounces per ton or 62.2 percent extraction.

(3) Added to .5 assay tons of raw ore 250 cc Cold H_2O and 15 cc $CuSO_4$ solution. Allowe to stand for one hour and add 15 grams of $Na_2S_2O_3$,heat to 55 degrees C and decant. Added 100 cc of cold H_2O and 15 cc $CuSO_4$ solution. Let stand for one hour and add 15 grams $Na_2S_2O_3$, heat to 55 degrees C filter and wash.

Assay of tails showed 9.76 ounces per ton or 63.92 percent extraction.

(4) To .5 assay tons of raw ore added 250 cc cold H_2O and 20 cc $CuSO_4$ solution and let stand for one hour. Add 20 grams $Na_2S_2O_3$ heat to 55 degrees and decant. Add 100 cc cold H_2O and 20 cc of $CuSO_4$, let stand one hour and add 20 grams $Na_2S_2O_3$,heat to 55 degrees C. filter and wash.

Assay of tails showed 4.6 ounces per ton or 83.01 percent extraction.

(5) To .5 assay tons raw ore add 250 cc cold H_2O and 25 cc $CuSO_4$, allow to stand one hour, add 20 grams $Na_2S_2O_3$, heat to 55 degrees C and decant. Add 100 cc cold H_2O and 25 cc $CuSO_4$ solution. Let stand for one hour and add 20 grams $Na_2S_2O_3$, Heat to 55 Degrees C. Filter and wash.

Assay of tails showed 3.92 ounces per ton or 85.5 percent extraction.

In the last experiments both the $CuSO_4$ and $Na_2S_2O_3$ were varied so to arrive at a definite conclusion a series of experiments were performed by varying the amount of $CuSO_4$ solution and keeping the amount of $Na_2S_2O_3$ constant. The amount of $Na_2S_2O_3$ used was 20 grams. The following results were obtained, using the same method of treatment as in the previous experiments.

Results.

Amt. of $CuSO_4$	Assay of tails	% of Extraction
10	8.64	68.10
12	6.64	79.18
14	5.98	79.77
16	5.12	81.10
18	4.55	83.20
20	4.36	83.90
22	4.21	84.46
24	3.90	85.60

As seen from the above results the best extraction is obtained when 24 cc of CuSO_4 are used. Another set of experiments were performed, keeping the CuSO_4 constant and varying the $\text{Na}_2\text{S}_2\text{O}_3$. The amount of CuSO_4 used was 25 cc. The following results were obtained, using the same method of treatment as before.

Results.

Amount of $\text{Na}_2\text{S}_2\text{O}_3$	Assay of Tails	Percent of Extraction.
5 grams	10.63	61.48
8	8.46	68.75
10	7.00	74.16
12	6.75	75.09
14	6.25	76.93
16	5.32	80.30
18	4.40	83.75
20	3.96	85.38

From the results obtained it is seen that the best maximum extraction is obtained by using 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$, so it may be concluded that to lixiviate the ore by this method these are the proper amounts of the reagents to use; that is, by using 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$ and 25 cc of CuSO_4 .

In a previous experiment it was found that an 84.2 percent extraction could be obtained by using 25 cc of CuSO_4 and 20 grams of $\text{Na}_2\text{S}_2\text{O}_3$ in 24 hours without any heat.

In the last experiment an 85.4 percent extraction was obtained by using 50 cc of CuSO_4 and 40 grams of $\text{Na}_2\text{S}_2\text{O}_3$ and heating for two hours at 55 degrees C.. It is now a question of this difference of

1.2 percent of extraction, together with this difference of 22 hours will off set the increase cost due to heating and doubling the amount of both solutions used.

As the increase in cost due to reagents and heating would be small as compared to the extra cost of labor and maintenance for the extra 22 hours; and as the capacity of the mill would be increased ten times by using the latter process the conclusion is reached that this is the best process of the two.

After comparing the foregoing results it is concluded that the most advantageous and economical method of lixiviating this ore in practice would be as follows:

Treat the ore with a two percent solution of CuSO_4 (enough to cover the ore) and allow to stand for one hour. Add enough $\text{Na}_2\text{S}_2\text{O}_3$ to form an eight percent solution. Heat to 55 degrees C and filter. Add a five percent solution of CuSO_4 (enough to cover this ore) and add enough $\text{Na}_2\text{S}_2\text{O}_3$ to form an eight percent solution. Heat to 55 degrees C. filter and wash.